International Journal of Applied Engineering
Research and Development (IJAERD)
ISSN(P): 2250-1584; ISSN(E): 2278-9383
Vol. 5, Issue 3, Aug 2015, 11-20

EFFECT OF SEVERAL PARAMETERS ON WAX DEPOSITION IN THE FLOW LINE DUE TO INDIAN WAXY CRUDE OIL

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ABSTRACT

This research article investigates the effect of several parameters on the wax deposition in a flow loop due to Indian waxy crude oil with the objective of the prediction of wax deposition in the flow lines and optimization of these parameters for the control of wax deposition problems in the tubing of an oil well and flow lines at the surface. The experimental studies were carried out to determine the effect of temperature differential, flow rate, residence time, and the concentration of pour point depressants on the wax deposition. It was found that there is significant variation in the wax deposition in the flow line due to these parameters and with the addition of a copolymer of fatty acid ester, polymeric additive, the wax deposition was reduced significantly which shows the potential of this additive for the control of flow assurance problems in the oilfields.

KEYWORDS: Wax Deposition, Paraffin Wax, Asphaltenes, Pour Point Depressant

INTRODUCTION

The wax deposition is a challenging problem in crude oil production and processing. Waxy crude oils contain significant amount of paraffin waxes and asphaltenes and these components creates a multitude of problems in reservoir, wellbore, production tubing and surface flow lines. It causes loss of production, reduced pipe diameter, increased horsepower requirements and negatively impacts production economics [1]-[6]. The deposition of these components in crude oil occurs due to their molecular structure. Asphaltene flocculation and wax crystallization are two mechanisms via which deposition takes place from crude oils. Paraffin/wax deposit and form solid crystals mostly due to lowering of temperature. Asphaltene deposition can occur only at thermodynamic conditions including variations of temperature, pressure, composition and flow rate. Resins are not known to deposit on their own, but they deposit together with asphaltenes [7]-[8].

The most common wax removal method is the mechanical method which uses pipeline pigs or scrappers. Pigs are devices launched from one end of the pipeline and retrieved from other end using either compressed air, water or the process liquid. The scrapers are conveyed by wire lines, sucker rods, and work strings used on a regular basis. They loosen the paraffin deposit which is further carried to the surface along with the flow of well fluids These pigs and scarppers are used for removal of blockage deposits and corrosion in pipeline to increase pump ability and reduce stress on pumping. But, traditional flow line-pigging operation requires the system to be shut down before launching the pig. This strategy results in significant loss of production for routine pigging. Also, recovery and disposal of deposits from flow lines during pigging and scrapping operations causes difficulties and add extra expenditures to increase the cost of oil production. The application heat in the waxy crude oil using hot oil or electrical heating, and application of chemicals (e.g. solvents, pour point dispersants) gives excellent results in controlling of wax deposition in the flow lines [9]-[12].

The chemicals used to control the wax deposition problems include solvents, dispersants, surfactants and wax crystal modifiers. Solvents are used to dissolve existing deposits. Certain solvents can cause problems with refining the produced crude oils. Diesel and xylene mixtures have been found to be very effective. Many proprietary formulations are also available for dissolving paraffin deposits**.** The wax control additives or pour point depressants are the polymers with pendant hydrocarbon chains that interacts paraffin in the crude and thus, inhibit the formation of large wax crystal matrix. The working mechanism of pour point depressant is that it disrupts the properties of the wax crystal matrix and increases the flowability of crude oil [13]-[16]

In this research article, different characteristics of an Indian waxy crude oil sample were determined for the study of the nature of waxy crude oil. Further, flow studies of the same sample were carried in the flow loop setup. The purpose of simulating flow-loop experiments was to assume an industrial condition and wax deposition behavior of crude oil flow in a flow line. This study is essential for simulating wax deposition in full-scale pipelines. Finally, the improvement in the flow behavior of this crude oil sample was studied after the addition of polymeric additives and the required concentration of pour point depressants was determined for the control of wax deposition problems in the flow lines.

EXPERIMENTAL WORK

The crude oil sample used in this study was procured from Oil and Natural gas Corporation, India. The characteristics crude oil include water content, density, specific gravity, API gravity, pour point and the cloud point. The density or API gravity, water content, and pour point of the waxy crude oil sample were determined using ASTM D 1298, ASTM D 96 and ASTM D 97 respectively. The cloud point or wax appearance temperature was determined by measuring viscosity over a range of temperature and taken to be a point at which a deflection in the slope occurs due to deviation from Newtonian behaviour as wax solids begin to form in the oil. The Brooke field viscometer was used for the determination of viscosity at different temperature. For the determination of wax content, 200 ml of petroleum ether was added to 6.0990 g of crude oil taken, then heated mildly & agitated thoroughly. After that it was transferred to a flat bottom flask. To this 45 g of fuller earth (surface active agent) was added and then agitated and heated after which it was allowed to remain stand still. Then ether was evaporated from the filtrate in a steam bath. 75% (150 ml) of acetone + 25 % (5 ml) of petroleum ether were added to the residue after evaporation. The resultant solution was then kept in cold water bath (-32 ^{o} C) for 15 to 20 minutes. After this it was filtered by gravity through normal filter paper. The difference of weight of filter paper plus wax after drying for 10-12 hours and weight of dry filter paper gave us the percentage of wax content. **.**

After the study of the characteristics of crude oil sample, the experiments were performed to study the pressure drop in the flow loop set up during the flow of crude oil (Figure 1). The components of flow-loop assembly include a 5 liter hot bath filled with the sample and it had privileges of heating the sample to 75 ^{o}C. The crude oil is pumped into the test-tube of the flow line surrounded by a cooling jacket which is continuously circulating cooling water over the test tube. Deposition process starts when circulating crude sample is cooled in the cooling jacket.

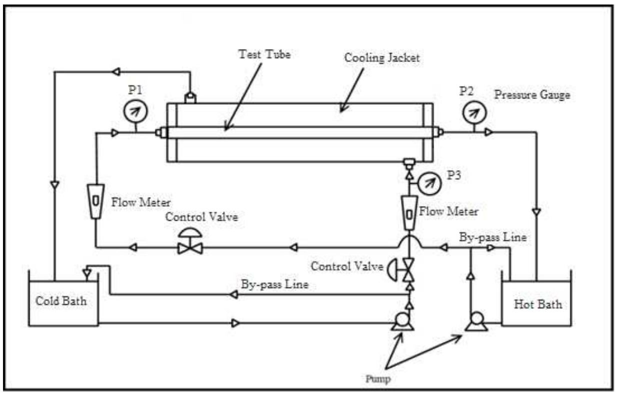

Figure 1: Schematic Diagram of the Flow Loop Setup

The weight of the test tube was initially determined and it was connected to complete the flow loop. The crude sample was heated to above 60 ^{o}C and then it was circulated in the test tube. Also, cold water is circulated in the cooling jacket from the cold bath.

The temperature of waxy crude oil and the cold water (coolant) as entered the flow loop set up were measured. The flow rate of crude oil was determined by measuring the volume of crude oil in the measuring cylinder for certain fixed time at the outlet of the test tube. After flowing the crude oil in the test tube for different time interval (residence time), the flow was stopped and diesel was circulated to wash the crude oil.

Finally, the test tube was disconnected from the set up and weight of the tube was again determined. The difference in the initial and final weight of the test tube gave us the amount of wax deposited in the flow line.

RESULTS AND DISCUSSIONS

The water content, API gravity, wax appearance temperature, pour point, wax content of crude oil sample are listed in Table 1. The crude oil in present study is a waxy crude oil having API gravity 32.

The wax appearance temperature is 57^{o}C and the pour point of the crude is + 36^{o}C with a wax content of 25 wt %.

Table 1: Characteristics of Crude Oils

Physical Parameters	Observed Values
Water Content (BS&W)	Nil
Pour point	+36 ^{o}C
Density	0.84 g/ml
Specific gravity	0.84
API gravity	32
Wax appearance temperature	57 ^{o}C
Wax content (% wt)	25

Effect of Temperature Differential on the Wax Deposition in the Flow Line

To study the effect of temperature differential on wax deposition, the crude oil sample is pumped into the flow-loop set up under different operating conditions. The wax deposition decreases with an increase in temperature difference between the oil and the pipe wall.

It was measured by measuring the temperature of waxy crude oil and the coolant as they enter the flow-loop. For wax deposition to occur, a temperature differential (ΔT) must exist between the waxy fluid and colder deposition surface. Table 2-6 and Figure 2-6 show the wax deposition against various waxy crude temperatures using same ratio of crude oil.

The temperature of the cooling water bath constantly fixed at 23°C. The results showed that as the temperature difference increases the paraffin wax deposition consistently decreases.

Table 2: Effect of Temperature Differential on Wax Deposition at 60 min

Temp Differential, ^{o}C	Wax Deposition, wt % @ 300 ml/min	Wax Deposition, wt % @ 400 ml/min	Wax Deposition, wt % @ 500 ml/min
17	1.301	1.287	1.241
22	1.205	1.163	1.097
27	1.1136	1.057	0.976
32	0.909	0.856	0.789

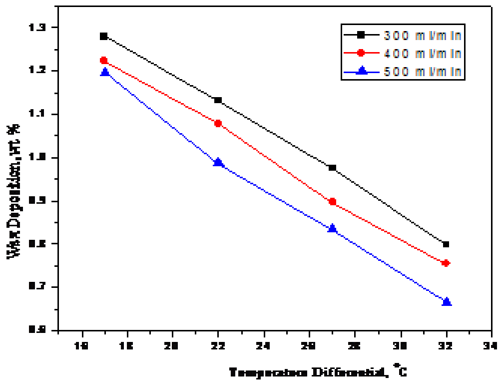

Figure 2: Effect of Temperature Differential on Wax Deposition at 60 min

Table 3: Effect of Temperature Differential on Wax Deposition at 120 min

Temp Differential, ^{O}C	Wax Deposition, wt % @ 300 ml/min	Wax Deposition, wt % @ 400 ml/min	Wax Deposition, wt % @ 500 ml/min
17	1.336	1.312	1.278
22	1.272	1.234	1.165
27	1.213	1.121	1.023
32	0.968	0.903	0.837

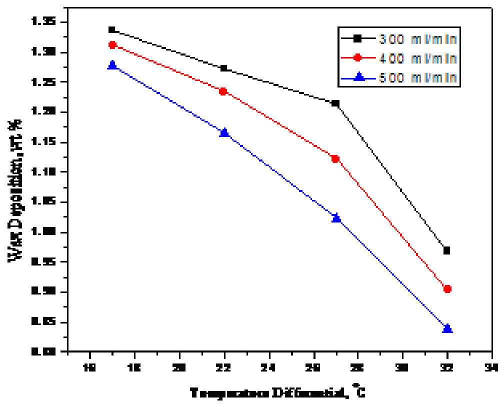

Figure 3: Effect of Temperature Differential on Wax Deposition at 120 min

Table 4: Effect of Temperature Differential on Wax Deposition at 180 min

Temp Differential, ^{O}C	Wax Deposition, wt % @ 300 ml/min	Wax Deposition, wt % @ 400 ml/min	Wax Deposition, wt % @ 500 ml/min
17	1.336	1.312	1.278
22	1.272	1.234	1.165
27	1.213	1.121	1.023
32	0.968	0.903	0.837

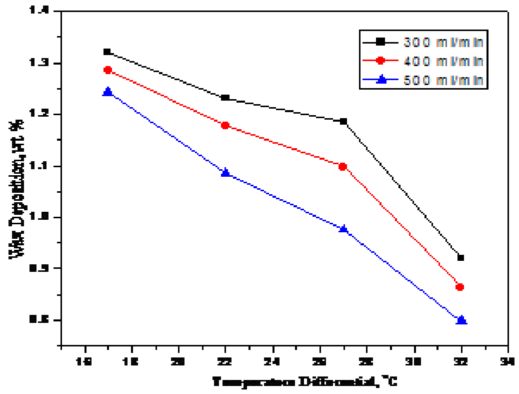

Figure 4: Effect of Temperature Differential on Wax Deposition at 180 min

Table 5: Effect of Temperature Differential on Wax Deposition at 240 min

Temp Differential, ^{O}C	Wax Deposition, wt % @ 300 ml/min	Wax Deposition, wt % @ 400 ml/min	Wax Deposition, wt % @ 500 ml/min
17	1.298	1.252	1.216
22	1.187	1.134	1.034
27	1.113	0.987	0.913
32	0.853	0.802	0.724

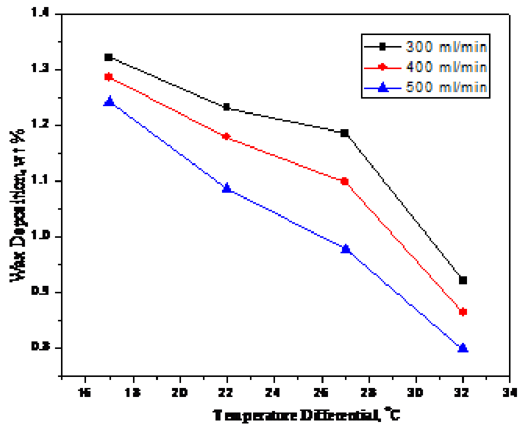

Figure 5: Effect of Temperature Differential on Wax Deposition at 240 min

Table 6: Effect of Temperature Differential on Wax Deposition at 300 min

Temp Differential, ^{O}C	Wax Deposition, wt % @ 300 ml/min	Wax Deposition, wt % @ 400 ml/min	Wax Deposition, wt % @ 500 ml/min
17	1.279	1.223	1.197
22	1.132	1.078	0.987
27	0.976	0.896	0.834
32	0.797	0.754	0.665

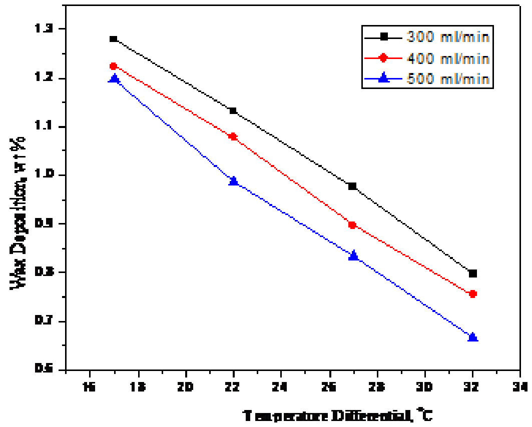

Figure 6: Effect of Temperature Differential on Wax Deposition at 300 min

Effect of Flow Rate on the Wax Deposition in the Flow Line

The Figures 7-11 shows that the amount of wax deposition depends on the flow rate or its equivalent production rate. In higher flow shear, which is a function of flow rate leads to lesser but likely harder deposit buildup. The wax deposition gradually decreases with increasing in flow rate and turbulence.

The wax deposits at a higher flow rate are harder and more compact. The effect of increasing flow rate decreasing the amount of wax deposited is entrapped oil.

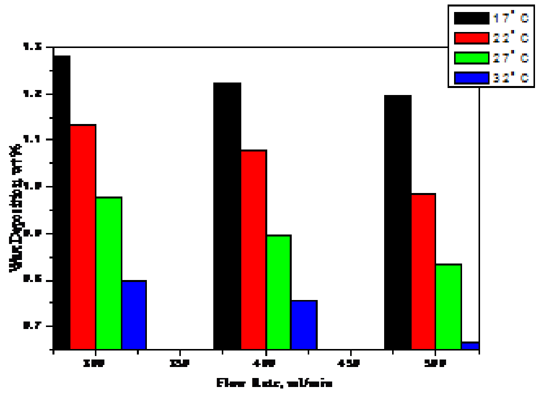

Figure 7: Effect of Flow Rate on Wax Deposition in 60 min

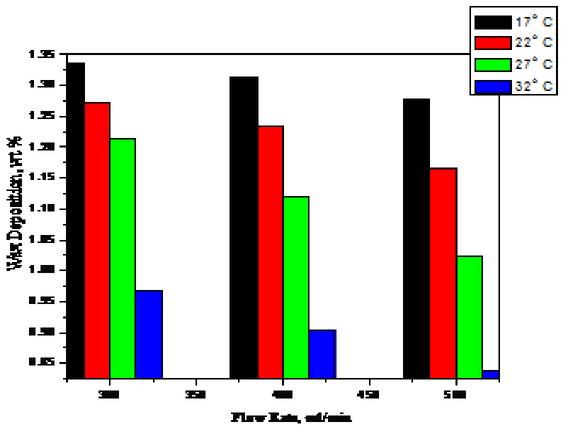

Figure 8: Effect of Flow Rate on Wax Deposition in 120 min

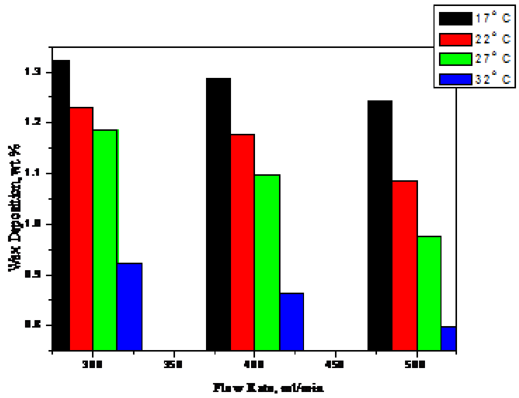

Figure 9: Effect of Flow Rate on Wax Deposition in 180 min

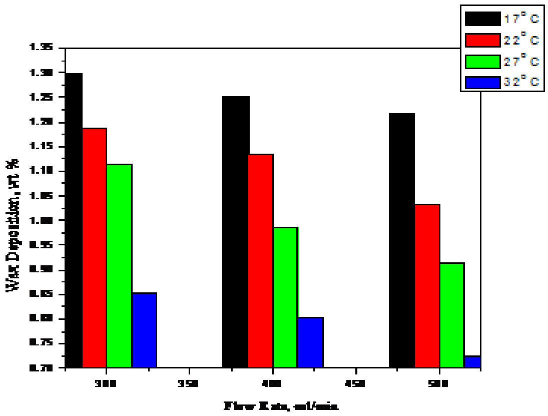

Figure 10: Effect of Flow Rate on Wax Deposition at 240 min

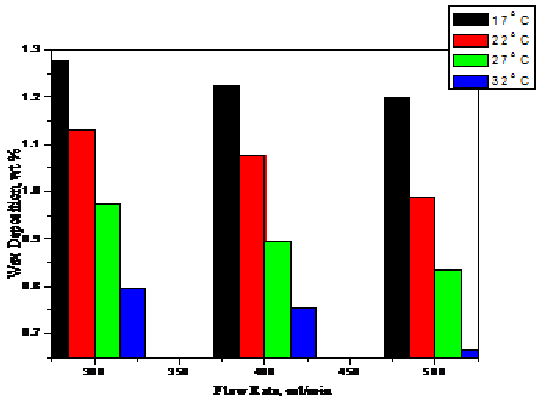

Figure 11: Effect of Flow Rate on Wax Deposition in 300 min

Effect of Residence Time on the Wax Deposition in the Flow Line

Table 7-8 shows the deposition of paraffin wax and total deposit build-up as a function of residence time of wax crude mixer for different flow rate and temperature differentia in to the thermal system. A graphical plot of wax deposit by % wt against residence time is shown in Figure 12-13. Initially the amount of wax deposition increased with increasing time which approximately becomes constant before gradually tailing off as time increases to higher values. The drop in paraffin wax deposition weight at higher value of time could be attributed to the thermal insulation by the deposited wax layer and the variation in at the amount of paraffin wax particle available for deposition.

Table 7: Effect of Time on Wax Deposition at 45° C

Time, Min	Wax Deposition, wt % @300ml/min	Wax Deposition, wt % @400 ml/min	Wax Deposition, wt % @500 ml/min
60	1.205	1.163	1.097
120	1.272	1.234	1.165
180	1.231	1.178	1.086
240	1.187	1.134	1.034
300	1.132	1.078	0.987

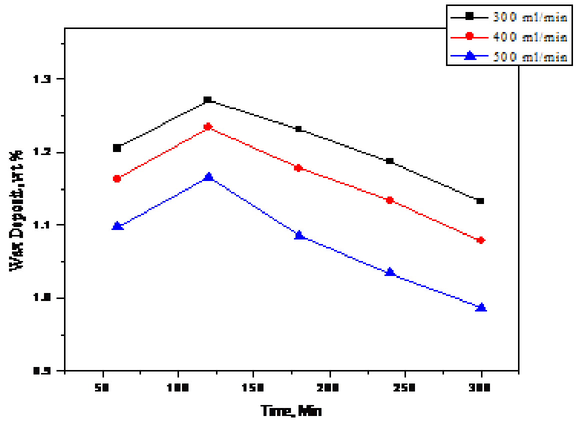

Figure 12: Effect of Time on Wax Deposition

Table 8: Effect of Time on Wax Deposition at 40° C

Time, Min	Wax Deposition, wt % @300ml/min	Wax Deposition, wt % @400 ml/min	Wax Deposition, wt % @500 ml/min
60	1.301	1.287	1.241
120	1.336	1.312	1.278
180	1.321	1.286	1.242
240	1.298	1.252	1.216
300	1.279	1.223	1.197

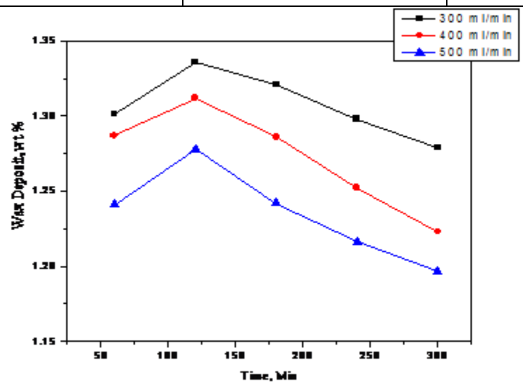

Figure 13: Effect of Time on Wax Deposition

Effect of Pour Point Depressant (PPD) on the Wax Deposition in the Flow Line

The effect of pour point depressant on wax deposition of the crude was studied by taking concentration of 750 ppm of copolymer of fatty acid ester, When this crude sample treated with additives, it is found that the additive has optimum effect on the wax deposition in flow line and reduced the wax deposition up to 60% at the temperature 40° C and 45° C. The effect of PPD on wax deposition is shown in Figure 14-15.

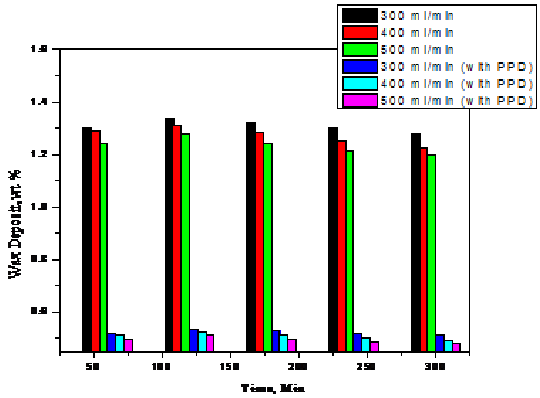

Figure 14: Effect of PPD on Wax Deposition at 40° C

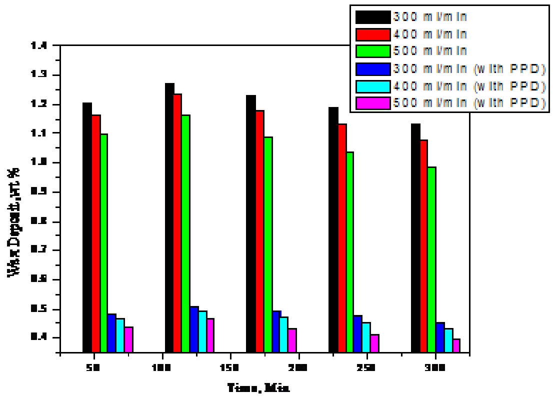

Figure 15: Effect on PPD on Wax Deposition at 45° C

CONCLUSIONS

The following conclusions are drawn from the present study:

- The amount of wax deposition increases with time and attain a maximum value and then gradually decreases
- Wax deposition decreases with an increase in temperature difference of crude oil and cooling jacket. .
- The wax deposition gradually decreases with increase in flow rate and turbulence. The wax deposits at higher flow rate are harder and more compact.
- Using pour point depressants the wax deposition can be reduced to 60% in the flow line.

ACKNOWLEDGEMENTS

The authors are very thankful to UGC New Delhi, India for providing financial support to carry out this research work.

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